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# Interactive Audio Pens, Home Literacy Activities and Emergent Literacy Skills

*Maximilian Pfost, Jana G. Freund*

## **Abstract**

Interactive audio pens – pens that contain a built-in speaker and that can be used in combination with books that are made for this purpose – are new, commercially available technological developments that have found widespread dissemination. In the current paper, we studied the availability and use of these interactive audio pens and their associations with home literacy activities and children's emergent literacy skills in a sample of 103 German preschool children. We found that the availability of interactive audio pens at home showed small positive relations to children's verbal short-term memory. Home literacy activities were not correlated to the availability of interactive audio pens. Results are discussed against the background of current research in multimedia storybook reading.

*Keywords:* interactive audio pens, emergent literacy skills, multimedia storybooks, home literacy environment, verbal short-term memory

*Zusammenhänge zwischen der Nutzung digitaler Lese- und Lernstifte mit der häuslichen Lernumwelt und schriftsprachlichen Vorläuferfähigkeiten*

## **Zusammenfassung**

In den letzten Jahren hat sich ein breites Angebot elektronisch gestützter Lesemedien etabliert. Besonders bekannt sind die digitalen Lese- und Lernstifte, das heißt elektronische Lesegeräte mit Lautsprecher in Stiftform, die beispielsweise zugehörige Kinderbücher nach Berührung des Buchtextes vorlesen. In der vorliegenden Studie (N = 103 Vorschulkinder) wurde kein statistisch bedeutsamer Zusammenhang zwischen der Verfügbarkeit digitaler Lese- und Lernstifte und der häuslichen Lernumwelt gefunden. Für die schriftsprachlichen Vorläuferfähigkeiten (Buchstabenkenntnis, phonologische Bewusstheit, verbales Kurzzeitgedächtnis) zeigt sich ein gering positiver korrelativer Zusammenhang der häuslichen Verfügbarkeit digitaler Lese- und Lernstifte mit dem verbalen Kurzzeitgedächtnis.

*Schlagwörter:* Digitale Lese- und Lernstifte, schriftsprachliche Vorläuferfähigkeiten, elektronische Kinderbücher, häusliche Lernumwelt, verbales Kurzzeitgedächtnis

## **1 Introduction**

It is widely acknowledged that the learning opportunities parents provide are pivotal for the development of their children's emergent literacy skills – skills that have been shown

to be substantially related to later reading and spelling achievement. Searching the most prominent precursor skills, meta-analyses, such as the study by *Scarborough* (1998) or the *National Early Literacy Panel* (2008), have reported that skills directly tied to the process of reading itself, for example, letter-name and letter-sound knowledge, are very good predictors of later reading achievement. Beyond these print-specific skills, researchers have emphasized the role of phonological processing abilities, such as verbal short-term memory and phonological awareness, for later reading and spelling development (*Melby-Lervåg/Lyster/Hulme* 2012; *Wagner/Torgesen* 1987). Verbal short-term memory denotes the ability of temporal storage and manipulation of verbal information (*Baddeley* 1992; *Wagner/Torgesen* 1987). Phonological awareness refers to the ability to reflect upon, detect, and manipulate the sound structure of oral language, independent of its meaning (*Anthony/Francis* 2005; *Pfof* 2015). However, recent studies comparing the importance of different predictors of reading achievement across orthographies have called into question the assumption that phonological processing abilities across orthographies, which differ in their transparency, carry equal importance (e.g. *Ziegler et al.* 2010). For the German orthography, for example, training studies on phonological awareness seemed less effective in comparison to the effect sizes reported in international literature (*Fischer/Pfof* 2015; *Wolf/Schroeders/Kriegbaum* 2016). Taken together, preschool aged children develop skills that facilitate their later reading development. As our interest is not limited to the question of the identification of such skills, we further ask whether we can identify variables and family activities that relate to individual differences in emergent literacy skills.

## 1.1 Storybook Reading, Electronic Storybooks, and Interactive Audio Pens

Besides formal approaches that are used to teach children to read and print words, parents often engage in several informal literacy activities with their children, such as joint storybook reading or visiting the library with their child (*Lehrl/Ebert/Rosbach* 2013; *Sénéchal et al.* 1998). These informal literacy activities have shown to be closely related to children's oral language and basic reading skills, including letter naming and phonological processing skills (*Bus/van Ijzendoorn/Pellegrini* 1995; *Mol/Bus* 2011). Parent's formal literacy activities, like teaching children to print words, have been shown to be of minor importance to children's oral language skills. However, substantial relations to children's letter knowledge were found (*Lehrl/Ebert/Rosbach* 2013; *Sénéchal et al.* 1998).

Nowadays, in addition to the analogue storybook, an increasing number of electronic multimedia devices, including electronic storybooks and e-book apps, are available. Electronic storybooks combine elements of traditional storybooks – text and pictures – with multimedia elements, such as an oral reading of the narrative, games or sound effects (*Bus/Takacs/Kegel* 2015). In a population representative sample of 2- to 8-year-old children in Germany, *Ehmig/Seelmann* (2014) showed that 16% of families have already tried electronic picture- and storybook apps, and data by *Rideout* (2014) showed that within the United States even 30% of the children have engaged in electronic reading. Regarding the effects of electronic multimedia storybooks on children's oral-language development and emergent literacy skills, a substantial number of experimental studies have provided convincing evidence for the beneficial effects of using such electronic multimedia storybooks (e.g., *Chera/Wood* 2003; *Korat/Segal-Drori* 2016; *Takacs/Swart/Bus* 2014). Such positive

findings from experimental studies were replicated in a correlational study that reported a positive association between preschoolers' access to touch screen tablets as well as home tablet activities and emergent literacy skills (Neumann 2014, 2016). Nevertheless, research has also shown that not every multimedia storybook or e-book app is equally well-designed with regard to their educational benefit. For example, design features that overload children's attentional resources or call their attention to semantically unrelated events may undermine such positive educational effects (Bus/Takacs/Kegel 2015). Consequently, more evaluation in natural observation settings, especially if these studies consider commercially available products, is warranted.

One commercially available product, which has found substantial dissemination in Germany and which shares many features with the above described multimedia storybook (e.g., the opportunity to have an autonomous interaction with the book), is the interactive audio pen. Technically, interactive audio pens<sup>1</sup> consist of two parts: First, there is the audio pen, which contains a built-in speaker (as well as a headphone jack). Second, there is the corresponding book. At first glance, the book looks like a traditional children's book as it is made out of paper and contains pictures and text passages. However, the book is sensitive to the interactive audio pen. If the child places the tip of the pen, which contains an electronic sensor, on a certain text passage, the pen reads the text aloud. These types of text passages are often relatively short in length, which is generally a common characteristic for storybooks designed for preschool children. In addition, most currently available books contain features such as games (e.g., searching specific objects printed on the page, quiz games, etc.), which are activated by placing the tip of the pen on special symbols on the page. Another feature is sound animations, activated by placing the pen tip on a mapped picture. Furthermore, a narrator may be activated explaining details and providing background information on the story content or additional facts. With regard to aspects of usability, the interactive audio pens and their corresponding books are designed in such a way that pre-schoolers, after a short introduction, can use them autonomously. In other words, due to the read-aloud function of the audio pen, even children who have not yet learned how to read are capable of "reading" such books. This is also supported by empirical findings which have shown that more than 60% of 4 to 6-year-old German preschoolers use interactive audio pens most of the time without parental support (Pfof/Freund/Becker 2018). The interactive books that are available in the German market encompass a wide range of topics (e.g., the forest, knights, or pirates). In addition, books explicitly dedicated to the learning of letters or numbers are available. Finally, besides the corresponding books, other products that can be used in combination with audio pens (e.g., a terrestrial globe, jigsaw puzzles, or several interactive [learning] games) are also available.

Despite its broad dissemination, interactive audio pens have not yet attracted a considerable amount of research. Apart from the findings by Pfof, Freund and Becker (2018; see above), we found one qualitative study on the use of interactive audio pens (Rechlitz et al. 2016). Based on parent interview data, the authors summarize that parents often consider interactive audio pens as an additional possibility for their children to get access to books and as a tool that supports children's reading motivation. Furthermore, the interviewed families described themselves as literacy-engaged families. These families indicated that reading is an important part of their life. Nevertheless, in addition to this interview study, the relation between the use of interactive audio pens and home literacy activities, such as joint storybook reading, have not yet been explored systematically. Further-

more, none of the above-mentioned studies explored relations to children's emergent literacy skills. Although untested scientifically, the availability of printed text, which may be read aloud by the pen after placing the tip of the pen on the text, may stimulate children's knowledge about the association between written text and oral language as well as general conventions on print. Indirectly, through an increase in letter knowledge, this may also promote children's phonological awareness. Finally, children's use of verbal short-term memory resources may be stimulated by games (e.g., the "I spy with my little eye" game) that require children to keep information active in their short-term memory.

## 1.2 Aims of the Present Study

Focusing on these research gaps, we addressed the following research questions in the present study: First, is the use of interactive audio pens related to parents' home literacy activities? As *Rechlitz et al.* (2016) have shown that parents consider interactive audio pens as an additional tool available for their children to get access to books; we expected a positive correlation between joint storybook reading and the availability of an interactive audio pen in the family. Second, is there a substantial relation between the availability of interactive audio pens in the household, the frequency of use of such interactive audio pens, and children's emergent literacy skills? Due to prior findings which have reported positive relations between joint book reading activities and emergent literacy skills as well as between electronic storybook reading and emergent literacy skills, we expected a positive relation between preschool children's use of interactive audio pens and their emergent literacy skills. As our major research interest was to explore individual differences in precursor skills of word reading, we focused on children's letter knowledge, phonological awareness and verbal short-term memory.

## 2. Method

### 2.1 Design and Participants

Eight kindergartens offered support for our correlational study. The kindergartens were located in two mid-sized cities (fewer than 100,000 inhabitants) in the region of northern Bavaria, Germany. We invited the parents of the children attending these kindergartens between the age of 4 and 6 to complete our questionnaire and to provide written consent for their children to participate in the study. In the end, 102 parent questionnaires were returned (response rate 32.8%). In one case, a parental couple provided consent to test two children (twins) but completed just one parent questionnaire. We tested both twins and assigned the (redundant) parent information to each twin. All children were tested individually and test sessions were scheduled between February and April 2016. The mean age of all children was 64.53 months ( $SD = 8.79$ ). Sixty-four (62.1%) children were male, and 39 (37.9%) were female. 88.1% of the mothers and 92.8% of the fathers indicated that they spoke German with their children most of the time if not exclusively. With regard to parent education, 69.7% of the mothers and 72.7% of the fathers had completed an upper-track school which allows university admission. According to data by the *Federal*

*Statistical Office* [Statistisches Bundesamt] (2016), 41.9-49.7% of adults between the age of 20 and 40 have completed upper-track school in Germany. Therefore, within our sample, families with higher education background were overrepresented.

## 2.2 Measures

*Interactive audio pens.* We asked parents to indicate whether they had one or more interactive audio pens for the children in their household. Furthermore, we listed two brand names (TipToi®, TING®) as examples. Response options were 1 = *yes* and 0 = *no*. Furthermore, if parents indicated that they possessed an interactive audio pen, we asked how often the child used this pen autonomously or alongside a parent. The frequency of use was rated on a five-point scale with the response options 5 (*every day*), 4 (*5-6 days a week*), 3 (*3-4 days a week*), 2 (*1-2 days a week*), and 1 (*less frequently or never*).

*Home literacy activities.* We asked parents to indicate how often they read storybooks to the child as well as how often they were engaged in letter and word writing activities with their children. The frequency of these informal (storybook reading) and formal (letter writing) home literacy activities were rated on a 5-point scale with the response options 5 (*every day*), 4 (*5-6 days a week*), 3 (*3-4 days a week*), 2 (*1-2 days a week*), and 1 (*less frequently or never*).

*Letter knowledge.* We presented 18 uppercase and ten lowercase letters printed on five pages (3 pages x 6 uppercase letters; 2 pages x 5 lowercase letters) to the children. Letters were presented in a random order, and the test material was adapted from the material developed by Moser/Berweger (2007). Children's letter knowledge scores were obtained by summing the number of correctly identified upper- and lowercase letters. The internal consistency of the test was very good ( $\alpha = .96$ ).

*Phonological awareness.* Phonological awareness was assessed with the sound-to-word comparison task developed by Jansen et al. (2002). For every item, the children were asked whether they could hear a certain vowel or diphthong in a given word. Ten words, preceded by a certain sound, were administered to the children following four practice items. Five times the word contained the preceding sound, and five times it did not. Each correct answer was given one point. The internal consistency of the test was satisfactory ( $\alpha = .75$ ).

*Verbal short-term memory.* Children listened to a series of 10 nonwords of increasing difficulty following two practice items. The nonwords were selected in accordance with the ones used by Jansen et al. (2002) and consisted of four to six syllables. The syllables were blended, and each nonword was pronounced like a real word. After pronouncing each nonword, the child was asked to repeat it. One point was given if the child could correctly repeat the nonword. The internal consistency was just acceptable ( $\alpha = .59$ ), reflecting the small number of items.

*Sociodemographic data.* The home questionnaire asked parents about their highest graduation certificate (the highest level of schooling they completed). Responses were summarized into three categories: 1 = *both parents have not completed upper-track school*; 2 = *one parent has completed upper-track school*; and 3 = *both parents have completed upper-track school*. In order to determine whether families were monolingual German

speakers, we asked parents to indicate whether they spoke with their child exclusively in German/mostly in German/sometimes in German/or exclusively in another language. Responses were summarized into three categories (family language use): 1 = *both parents have spoken exclusively/mostly German with their child*; 2 = *one parent has spoken exclusively/most of the time German with their child*; and 3 = *none of the parents has spoken exclusively/most of the time German with their child*.

### 2.3 Analyses

In a first step, we computed zero-order correlations and partial correlations to correct for age differences in the children. In a second step, we analyzed individual differences in letter knowledge, phonological awareness, and verbal short-term memory in relation to the availability and use of interactive audio pens as well as home literacy activities in a set of regression analyses. Thereby, we took children's gender and age, parents' education (dummy-coded), as well as family language use (dummy-coded) – possible confounding variables due to the often observed relations with children's literacy skills – as covariates into account. In order to avoid a substantial reduction in the sample size due to the concurrent use of multiple indicators in the regression analyses, missing data were replaced via multiple imputation. We used 20 imputations in order to get a sufficiently precise estimate of the standard errors.

## 3 Results

*Table 1:* Descriptive Statistics

	Scale range	<i>n</i>	<i>M (SD)</i>	<i>Mdn</i>
Audio pens – Availability	0-1	100	0.66 (0.48)	1.00
Audio pens – Frequency of use	1-5	66	1.82 (0.94)	2.00
Frequency of storybook reading	1-5	100	4.39 (1.01)	5.00
Frequency of letter writing	1-5	99	2.70 (1.25)	3.00
Letter knowledge	0-28	95	7.83 (8.12)	4.00
Phonological awareness	0-10	95	8.22 (2.09)	9.00
Verbal short-term memory	0-10	94	6.38 (2.01)	7.00
Family language – combined scale <sup>a</sup>	1-3	97	1.19 (0.49)	1.00
Parents education – combined scale <sup>b</sup>	1-3	99	2.41 (0.78)	3.00
Children's gender (1 = female)	0-1	103	0.38 (0.49)	0.00
Children's age (in months)	45-88	103	64.53 (8.79)	64.00

*Note:* Except for children's age, the scale range indicates the theoretical minimum and maximum of the scale. For children's age, the empirical minimum and maximum are shown. <sup>a</sup>Family language: 1 = both parents speak German with the child; 2 = one parent speaks German with the child; 3 = none of the parents speaks German with the child. <sup>b</sup>Parents education: 1 = both parents have not completed upper-track school; 2 = one parent has completed upper-track school; 3 = both parents have completed upper-track school.

### 3.1 Descriptive Statistics

Table 1 presents univariate statistics for our variables of interest. The descriptive data shows that interactive audio pens have been broadly disseminated. In our sample, 66.0% of the children had access to interactive audio pens at home. Within the group of children who had access to these audio pens, 84.8% of the parents indicated that their children used these pens a mere 1-2 days a week or even less frequently. For comparison: 82.0% of the parents reported joint storybook reading activities on a daily or almost daily basis.

*Table 2: Zero-Order Correlations and Partial Correlations Controlling for Children's Age*

	1	2	3	4	5	6	7	8	9	10
1 Audio pens – Availability		(-)	.08	-.05	.11	.09	.23*	-.12 <sup>a</sup>	-.09 <sup>a</sup>	-.10
2 Audio pens – Frequency of use	(-)		.00	.16	-.14	-.13	.16	.23 <sup>a</sup>	.11 <sup>a</sup>	-.03
3 Storybook reading	.09	.00		.13	.03	.02	.08	.11 <sup>a</sup>	.38*** <sup>a</sup>	-.06
4 Letter writing	-.09	.15	.11		.17	.09	.03	.04 <sup>a</sup>	-.02 <sup>a</sup>	.18
5 Letter knowledge	.03	-.14	.00	.27**		.26*	.13	.22* <sup>a</sup>	.33*** <sup>a</sup>	.00
6 Phonological awareness	.03	-.13	.00	.18	.37**		.26*	.02 <sup>a</sup>	.09 <sup>a</sup>	-.22*
7 Verbal short-term memory	.18	.14	.06	.11	.23*	.33**		.04 <sup>a</sup>	.04 <sup>a</sup>	.07
8 Family language use	-.12 <sup>a</sup>	.23 <sup>a</sup>	.11 <sup>a</sup>	.03 <sup>a</sup>	.20 <sup>a</sup>	.02 <sup>a</sup>	.05 <sup>a</sup>		.16 <sup>a</sup>	-.20 <sup>a</sup>
9 Parents education	-.08 <sup>a</sup>	.11 <sup>a</sup>	.38*** <sup>a</sup>	-.03 <sup>a</sup>	.23* <sup>a</sup>	.04 <sup>a</sup>	.00 <sup>a</sup>	.16 <sup>a</sup>		-.01 <sup>a</sup>
10 Children's gender (1 = female)	-.09	-.03	-.06	.16	-.02	-.22*	.06	-.20 <sup>a</sup>	-.01 <sup>a</sup>	
11 Children's age	-.15	-.02	-.06	.28**	.43**	.36**	.28**	.04 <sup>a</sup>	-.09 <sup>a</sup>	-.03

*Note:* Zero-order correlations are shown below the diagonal. Partial correlations controlling for children's age are shown above the diagonal. *N* varies from 62 to 103 due to pairwise deletion.

<sup>a</sup>Correlations substituted by Spearman's rho.

\*  $p < .05$ . \*\*  $p < .01$ .

### 3.2 Intercorrelations

Table 2 shows intercorrelations: zero-order correlations are presented below the diagonal, and partial correlations corrected for age effects are presented above the diagonal. We could not find any relations between the use of interactive audio pens with parents' home literacy activities. Neither joint book reading activities nor the writing of letters and words were related to the availability ( $r = .09$ , *ns*, for storybook reading; and  $r = -.09$ , *ns*, for letter writing) and frequency of use ( $r = .00$ , *ns*, for storybook reading; and  $r = .15$ , *ns*, for letter writing) of the interactive audio pens.

The availability and frequency of use of the interactive audio pens were not directly related to children's letter knowledge and phonological awareness. Concerning the association between the availability of interactive audio pens at home and verbal short-term memory, we observed a descriptive tendency toward a positive correlation ( $r = .18$ , *ns*). Contrary to joint storybook reading activities, which were not related to children's emergent literacy, parents' engagement in joint letter and word writing activities was positively related to children's letter knowledge ( $r = .27$ ,  $p < .01$ ). Apart from two exceptions, correlations that controlled for age effects confirmed the above-mentioned relations: parents' engagement in joint letter and word writing activities did not anymore relate to chil-



dren's letter knowledge ( $r = .17$ ,  $ns$ ). And, after controlling for age, we observed a significant relation between the availability of interactive audio pens and verbal short-term memory at the 5% level ( $r = .23$ ).

**Table 3:** Regression Analyses Predicting Individual Differences in Emergent Literacy Skills ( $n = 103$ )

	Letter knowledge $B$ ( $SE$ )	Phonological awareness $B$ ( $SE$ )	Verbal short-term memory $B$ ( $SE$ )
Constant	0.58 (3.98)	6.57 (1.22)**	4.66 (1.17)**
Children's gender (1 = female)	0.15 (1.63)	-0.99 (0.47)*	0.46 (0.47)
Children's age <sup>a</sup>	0.39 (0.09)**	0.08 (0.03)**	0.08 (0.03)**
Family language (1 = occasionally German) <sup>b</sup>	2.31 (2.41)	0.85 (0.66)	0.27 (0.67)
Family language (1 = other language) <sup>b</sup>	3.94 (3.93)	-1.75 (1.12)	0.05 (1.15)
Parents education (1 = one upper-track) <sup>c</sup>	3.50 (2.75)	1.52 (0.74)*	0.17 (0.77)
Parents education (1 = both upper-track) <sup>c</sup>	6.71 (2.40)**	1.14 (0.67)	0.48 (0.65)
Storybook reading <sup>a</sup>	-0.59 (0.95)	0.01 (0.27)	0.11 (0.27)
Letter writing <sup>a</sup>	0.89 (0.67)	0.21 (0.19)	-0.03 (0.18)
Audio pens – Availability	3.28 (1.72)	0.40 (0.51)	1.20 (0.50)*
$F^2$	0.313	0.271	0.175

*Note:* Missing values were multiply imputed ( $m = 20$ );  $R^2$  was estimated by taking the arithmetic mean of the 20 data sets;

<sup>a</sup> Centered around the grand mean. <sup>b</sup> Reference group is both parents speak German with their child.

<sup>c</sup> Reference group is none of the parents completed upper-track school.

\*  $p < .05$ . \*\*  $p < .01$

### 3.3 Availability of Audio Pens at Home and Emergent Literacy Skills

In order to trace the relations of the availability of interactive audio pens at home and home literacy activities with emergent literacy skills, we further conducted a set of regression analyses. The results are presented in Table 3. The availability of an interactive audio pen at home was not related to children's letter knowledge: Although in descriptive terms children within our sample who had access to an interactive audio pen on average knew about 3.28 ( $SE = 1.72$ ,  $ns$ ;  $SD_{pooled} = 8.14$ ,  $d = 0.40$ ) letters more than children who did not have access to an interactive audio pen at home, this difference did not reach statistical significance. Similar to children's letter knowledge, we did not find a relation between the availability of interactive audio pens and phonological awareness ( $B = 0.40$ ,  $SE = 0.51$ ,  $ns$ ;  $SD_{pooled} = 2.17$ ,  $d = 0.18$ ). However, the availability of interactive audio pens was positively related to children's verbal short-term memory ( $B = 1.20$ ,  $SE = 0.50$ ,  $p < .05$ ). That is to say, for a task involving 10 items, children who had an interactive audio pen at home were able to replicate an average of 1.20 more nonwords in comparison with children who did not own such an interactive audio pen. With regard to the pooled standard deviation of 2.07, this finding is equal to a difference of  $d = 0.58$  standard deviations.

### 3.4 Frequency of Use of Interactive Audio Pens and Emergent Literacy Skills

In the subsample of children who had an interactive audio pen at home ( $n = 66$ ), the frequency of use of these pens was analyzed in relation to the children's emergent literacy skills. After considering all of the control variables, we did not find an association between the frequency of use of interactive audio pens and short-term memory ( $B = 0.07$ ,  $SE = 0.27$ ,  $ns$ ) or with phonological awareness ( $B = -0.26$ ,  $SE = 0.30$ ,  $ns$ ). However, letter knowledge was negatively related to the frequency of use of interactive audio pens ( $B = -2.44$ ,  $SE = 1.08$ ,  $p < .05$ ). In other words, frequent users of such pens showed lower letter knowledge.

## 4 Discussion

An inspection of the descriptive results revealed a high dissemination of interactive audio pens in our sample. Two thirds of the children in our sample had access to audio pens at home. This shows that a substantial proportion of children had experience with electronic aids, underscoring the popularity of digitally enhanced storybooks. Parents indicated that most preschoolers just used these pens 1 to 2 days a week. Therefore, although children can use such pens autonomously (*Pfost/Freund/Becker* 2018), traditional home literacy activities, such as joint storybook reading, were still more prevalent.

Contrary to our expectations, the availability and use of interactive audio pens at home was neither related to parents' informal home literacy activities (joint storybook reading) nor to parents' formal home literacy activities (letter writing). Qualitative findings have shown that families who own an interactive audio pen describe themselves as being literacy engaged. These parents have indicated that the activity of reading is an important part of their life and that they have been engaged in promoting their children's exposure to books (*Rechlitz et al.* 2016). Although our findings may not directly contradict this statement due to a lack of a more comprehensive measure of the home literacy environment (cf. *Niklas/Schneider* 2013), this result might provide an initial indication that interactive audio pens, and perhaps further electronic reading devices, may not easily be subsumed within the (traditional) home literacy construct.

### 4.1 Interactive Audio Pens and Emergent Literacy Skills

We expected to find positive relations for the availability and use of interactive audio pens with emergent literacy skills. The results of the regression analyses that took several covariates into account (inter alia parents' education and family language, children's age and gender) showed a small but significant positive relation between the availability of interactive audio pens at home with children's verbal short-term memory. We found no relation between the availability of interactive audio pens and children's phonological awareness or letter knowledge. Finally, within families that reported having an interactive audio pen at home, the frequency of use of such pens was negatively related to letter knowledge.

The relation between access to interactive audio pens and verbal short-term memory may be explained through a close inspection of the content of the books that can be used with these interactive audio pens. This inspection reveals that many books include games, which rely heavily on children's short-term memory resources. For example, in the most prominent book within our sample – "Discover the farm" – the child does not just have the opportunity to play the "I spy with my little eye" game, but can also play a game in which the pen lists up to six objects (e.g., a cockerel, an egg, etc.), from which the child subsequently has to identify the objects on the page of the storybook by using the tip of the pen. As verbal short-term memory is potentially alterable through working memory training (Melby-Lervåg/Hulme 2013), children who regularly play games that contain components such as remembering and identifying certain objects might improve their verbal memory skills. However, prior research has also called into question the assumption that the effects of training ones verbal short-term memory skills transfers into further academic outcomes, including reading skills (Redick et al. 2015). Furthermore, we need to be cautious in the interpretation of the direction of this finding. Besides the interpretation that such books and games might improve children's verbal memory skills, it is equally likely that children with better verbal memory skills also have a higher interest in the use of interactive audio pens and in playing its games. Finally, a third variable like children's intellectual ability, which has not been considered in our analyses, might explain this association.

Within the subgroup of children who had access to an interactive audio pen, our findings that took several covariates into account revealed a negative relation between the frequency of use of interactive audio pens and letter knowledge. However, in descriptive terms, a slight positive relation between letter knowledge and the availability of interactive audio pens at home was observed, but this relation did not reach a level of statistical significance. Both relations were not present in zero-order correlations, which further restrains a meaningful interpretation of this inconsistent result pattern. Another interpretation difficulty arose from the fact that there was little variance in parents' statements on the frequency of use of interactive audio pens. On the one hand, the frequency of use of interactive audio pens was on average quite low. On other hand, the response scale was not very fine grained as there were only five different response options offered. In consequence, before too much confidence can be placed in this negative/positive relation, a replication of this finding is needed.

## 4.2 Limitations

First, with regard to the research design, our results were based on a limited sample of 103 children and their parents, and both were only studied cross-sectionally. In addition to this, our sample was not representative of the full heterogeneity of families and children living in Germany. As the sample was not representative of the full population of German children attending kindergarten, a bias, for example with regard to the proportion of children who had access to audio pens at home, might have occurred. More precise estimates may be achieved by considering more children/families and a sampling bias might be prevented through the application of a representative sampling procedure. In addition, the validity of our interpretation, especially with regard to the question of causal effects, might benefit from implementing a longitudinal study design that contains a broader con-

sideration of potential confounding variables and perhaps even experimental manipulation. This limitation seems especially important for the interpretation of our finding of a positive relation between access to interactive audio pens and verbal short-term memory. Second, we focused on three measures that are central to the concept of emergent literacy skills, and our phonological awareness as well as verbal short-term memory measures were quite brief and had restricted reliability. Another limitation concerns the operationalization of the phonological awareness construct. Phonological awareness encompasses different sizes of sound units and different cognitive operations. However, as we only applied a single sound-to-word comparison task, future research might benefit from using broader and longer instruments. The subskills we measured may be categorized as being directly code-related. We included no measures of oral-language skills (e.g., vocabulary or syntactic knowledge) that might be equally worthy of being evaluated with regard to the use of interactive audio pens and further technological advances in the field of early education. Finally, we relied on self-report measures of home literacy activities and interactive audio pens, which may be confounded with social desirability. Therefore, future studies might triangulate parent self-report data with live observations in authentic contexts. Furthermore, with regard to the frequency of storybook reading, we observed a tendency toward a ceiling effect, which restricts variation and reduces correlations. In sum, future studies might benefit from using more comprehensive measures when studying the home literacy environment.

### 4.3 Outlook

Commercially available products such as electronic storybooks or interactive audio pens have already reached - at least in Germany - widespread dissemination. Experimental results have provided guidance that help engineers and publishers develop cognitively stimulating tools and help parents select age-appropriate and adequate products (see *Bus/Takacs/Kegel* 2015, for an overview). However, little is known about the use of these products and how their use relates to further aspects, such as parents' home literacy activities and literacy development. First results show a minor positive correlation between the use of interactive audio pens and verbal short-term memory. Nevertheless, we are just beginning to understand relations and effects of a changing media environment on children's literacy development (*Neumann/Finger/Neumann* 2017). Therefore, further research, especially in ecologic valid settings and authentic contexts, is needed

### Annotations

- 1 A short introduction to one of the commercially available interactive audio pens is available on the product website <http://www.tiptoi.com/> [February 20, 2018]. The authors did not receive any financial or material support from any of the products discussed in this paper. We are also not recommending any one specific commercially available product.

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